ACE Lidar Simulation Study

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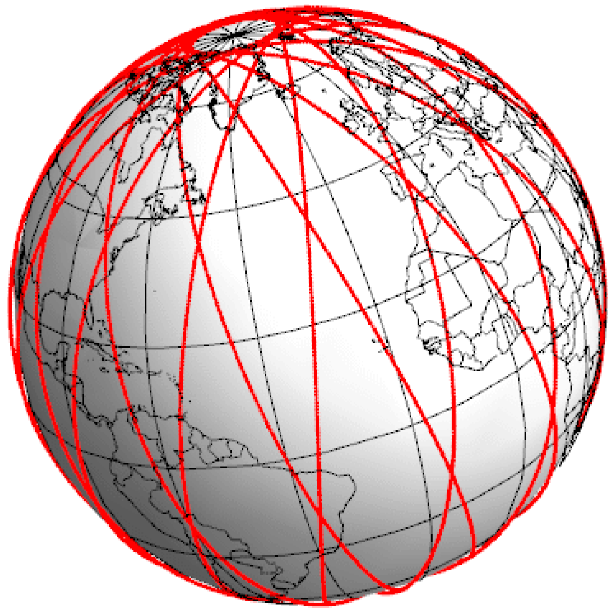
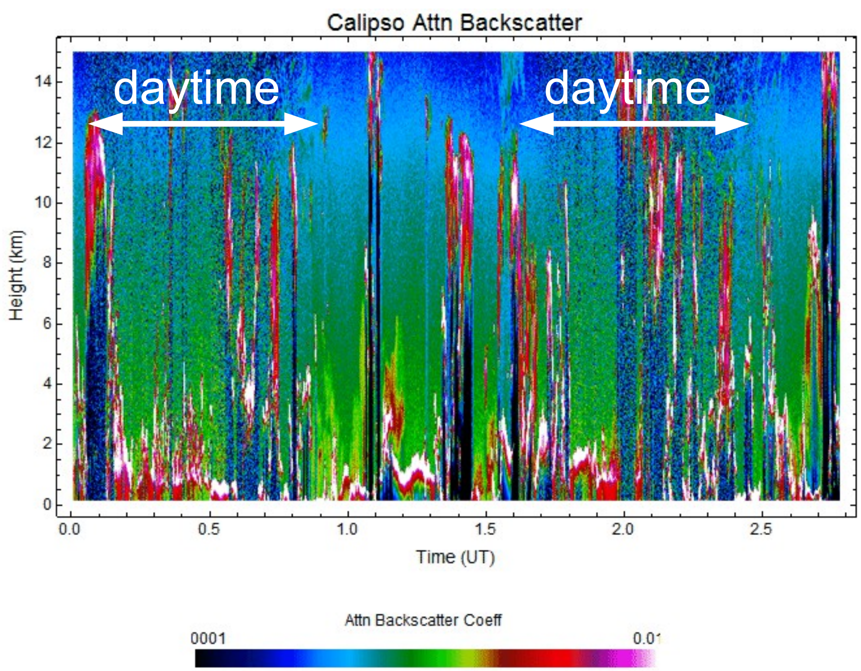
with help and helpful feedback from Steve Palm and LaRC (Rich Ferrare, Chris Hostetler, Jon Hair, Kathleen Powell, Detlef Muller)

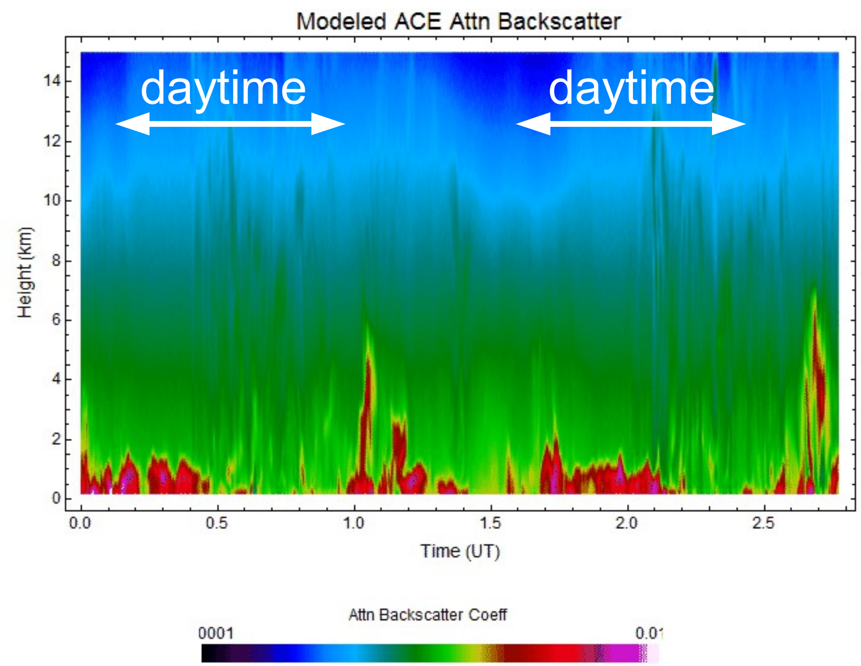
Approach

- Simulate HSRL lidar measurements for full Calipso orbit July 15, 2009 at 10 s resolution
  - Density and 3+2 aerosol optical profiles from GEOS-5
  - Radiance values from RT model (VLIDORT)
- Study yields for microphysical retrievals considering both 3+1 and 3+2 configurations
- Study microphysical inversions using these data



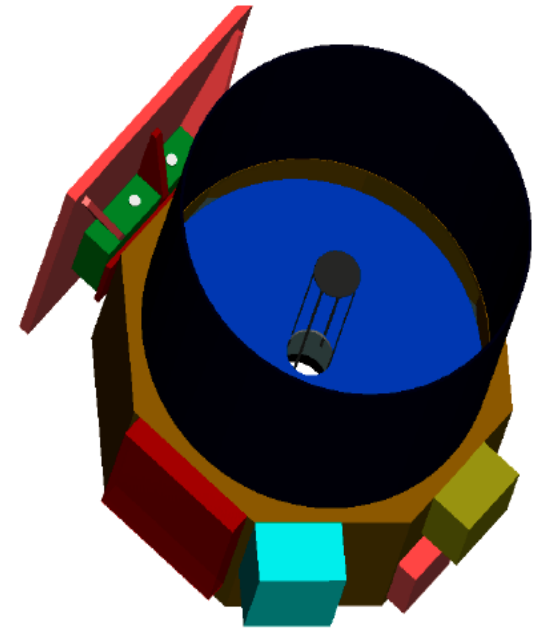
Calipso track for July 15, 2009.

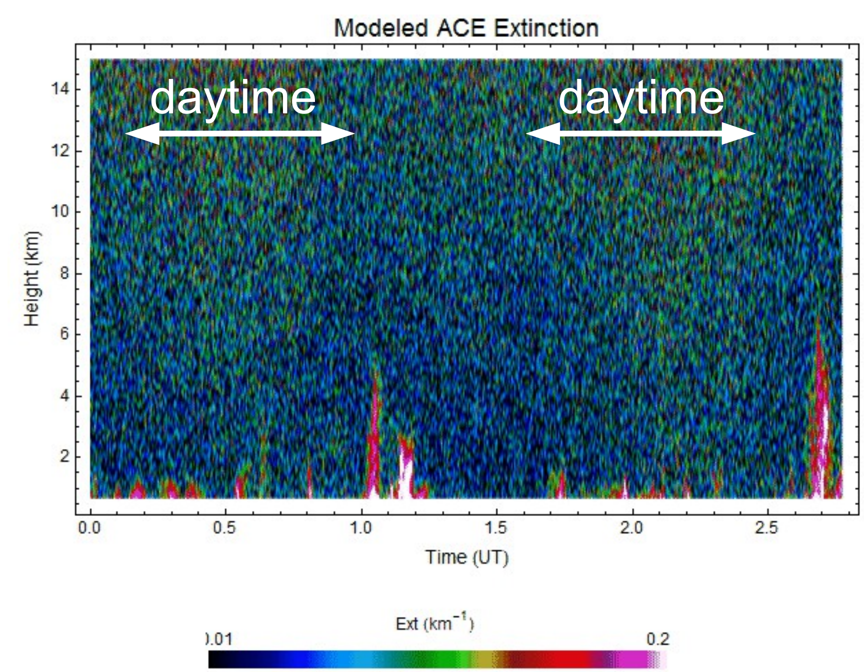




What Lidar hardware is simulated?

- Orbital altitude : 450 km (820 km)
- Laser : 100 Hz, 10W @ 1064 and 532nm, 5W @ 355 nm
- Telescope : **1.0 m** and 1.5 m
- FOV : 130 microrad
- Filter Bandpass : 30 pm @ 355, 532 nm, 20 pm @ 1064 nm
- Detector QE = 60%
- Photon pile-up turned off so analog detection simulated
- Optical efficiencies
  - molecular = 0.16
  - particle = 0.04





Optical Data Studied

- “3+2” configuration
  - 3 backscatter (355nm, 532nm, 1064nm), 2 extinction (355nm, 532nm)
  - supports retrieval of PSD and volumetric quantities
- “3+1” configuration
  - 3 backscatter (355nm, 532nm, 1064nm), 1 extinction (532nm)
  - supports retrieval of volumetric quantities
- 355 nm extinction measurement needed for
  - reasonable retrievals of the PSD
  - estimates of absorption

Microphysical Retrieval Techniques Studied

- **Regularization** (Twomey, 1977, Müller et al., 1999, Veselovskii et al., 2002)
  - Using a linear combination of triangular basis functions
  - Permits retrieval of features of the size distribution when coupled with 3+2 optical data
  - Slow but can be sped up through use of look-up tables
- **Linear Estimation** (Twomey, 1977, Donovan and Carswell, 1997, Veselovskii et al., 2012, De Graaf et al., 2013)
  - expands in terms of Mie kernels
  - retrieves volumetric quantities, not size distribution
  - faster execution and greater tolerance to input noise
- Under-determined problem with limited input data
  - method of solution and constraints used influence the results obtained
  - additional information to decrease inversion intervals can improve solutions
- Technique of retrieval comparison
  - Consider inversions based on GEOS-5 optical inputs as “reference” and quantify distortion through the simulated measurement process

Yield Comparison – 450 km Orbit
(w/1.0 m telescope and no clouds)

3+2 Retrieval Yield (volumetric quantities and estimate of PSD)

"Point": 80 km horizontal resolution, 450 m vertical resolution	**whole orbit** with extinction threshold (0.02km^{-1}) met	**whole orbit.** qualifying bins measured with 15% uncertainty	**overland.** with extinction threshold (0.02km^{-1}) met	**overland** pct qualifying bins measured with 15% uncertainty
Below 5 km	18%	9.7%	27%	9.3%
Below 4 km	21%	9.9%	31%	9.7%
Below 3 km	27%	10%	36%	10%

3+1 Retrieval Yield (volumetric quantities only)

"Point": 80 km horizontal resolution, 450 m vertical resolution	**whole orbit** with extinction threshold met	**whole orbit** with extinction and error met	**overland.** with extinction threshold met	**overland** pct qualifying bins measured with 15% uncertainty
Below 5 km	18%	26%	27%	25%
Below 4 km	21%	27%	31%	26%
Below 3 km	27%	27%	36%	26%

Yield for volumetric quantities ~2.5x higher for 3+1 retrievals versus 3+2

Yield Comparison – 820 km Orbit

(w/1.0 m telescope and no clouds)

3+2 Retrieval Yield (volumetric quantities and estimate of PSD)

"Point": 80 km horizontal resolution, 450 m vertical resolution	**whole orbit** with extinction threshold (0.02 km^{-1}) met	**whole orbit.** qualifying bins measured with 15% uncertainty	**overland.** with extinction threshold (0.02 km^{-1}) met	**overland** pct qualifying bins measured with 15% uncertainty
Below 5 km	18%	3.0%	27%	2.9%
Below 4 km	21%	3.1%	31%	3.1%
Below 3 km	27%	3.1%	36%	3.0%

3+1 Retrieval Yield (volumetric quantities only)

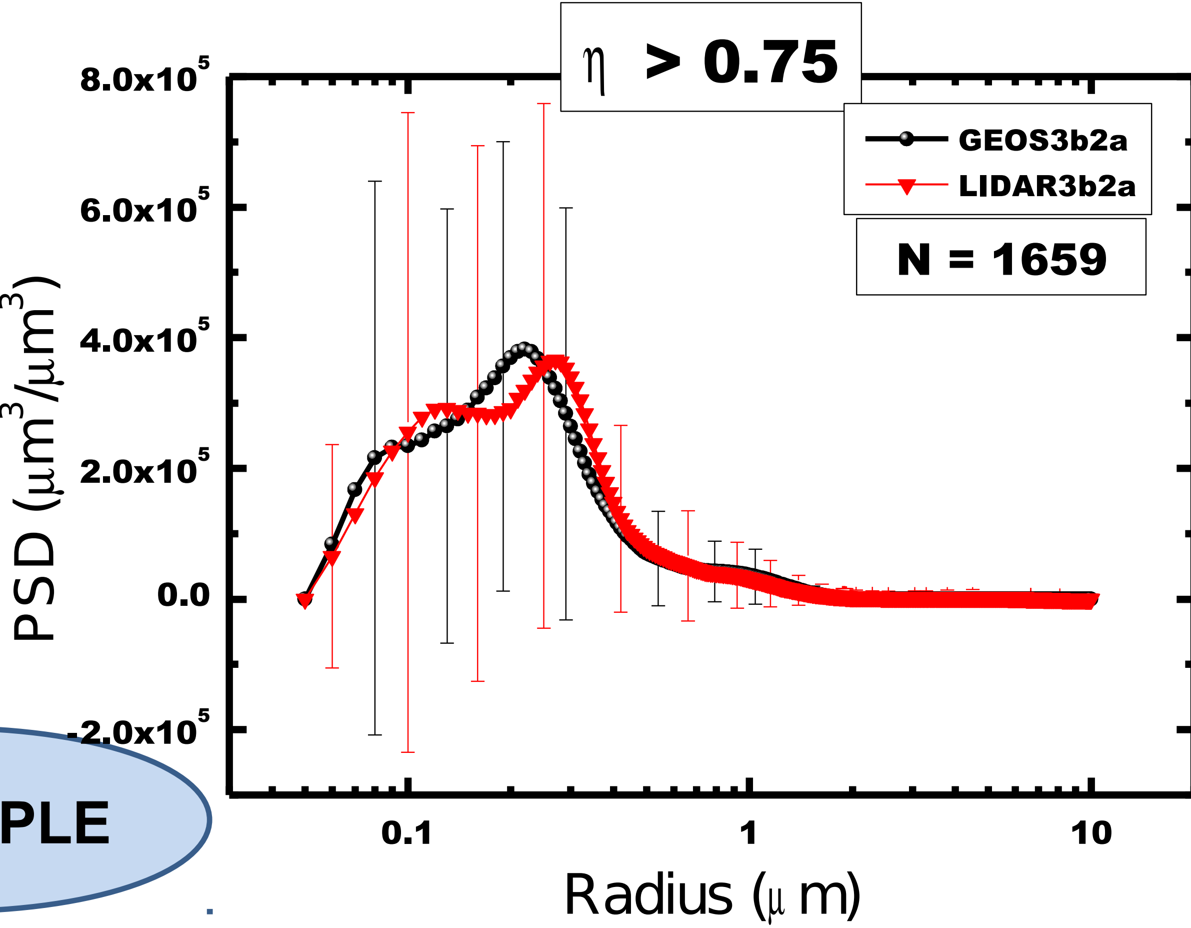
"Point": 80 km horizontal resolution, 450 m vertical resolution	**whole orbit** with extinction threshold met	**whole orbit** with extinction and error met	**overland.** with extinction threshold met	**overland** pct qualifying bins measured with 15% uncertainty
Below 5 km	18%	14%	27%	14%
Below 4 km	21%	15%	31%	15%
Below 3 km	27%	15%	36%	15%

Yield for volumetric quantities ~5x higher for 3+1 retrievals versus 3+2

Systematic Uncertainty Study

- Regularization with 3+2 optical input
  - Retrievals more sensitivity to uncertainties in extinction than backscatter
  - Linear relationships between systematic uncertainties and retrieved properties
  - Individual channel results are additive
    - permitted random uncertainty study to be done
  - supports trade studies among the various optical channels
- 15% uncertainties in all input optical data translate to the following uncertainties in microphysical retrievals using 3+2 and Regularization (ACE goal)
  - R_{eff} = 37-39% (20% when extinction in layer exceeds 0.05 km^{-1})
  - N_{conc} = 68-95% (100%)
  - ω_0 = ? (0.02) not presented in paper due to large sensitivity of retrieved m to the range of mi permitted in the retrievals.

Effects of systematic and random errors on the retrieval of particle microphysical properties from multiwavelength lidar measurements using inversion with regularization, D. Pérez-Ramírez, D. N. Whiteman, I. Veselovskii, A. Kolgotin, M. Korenskiy, and L. Alados-Arboledas, Atmos. Meas. Tech., 6, 3039-3054, 2013



MEAN SIZE DISTRIBUTIONS: FINE MODE PREDOMINANCE

EXAMPLE

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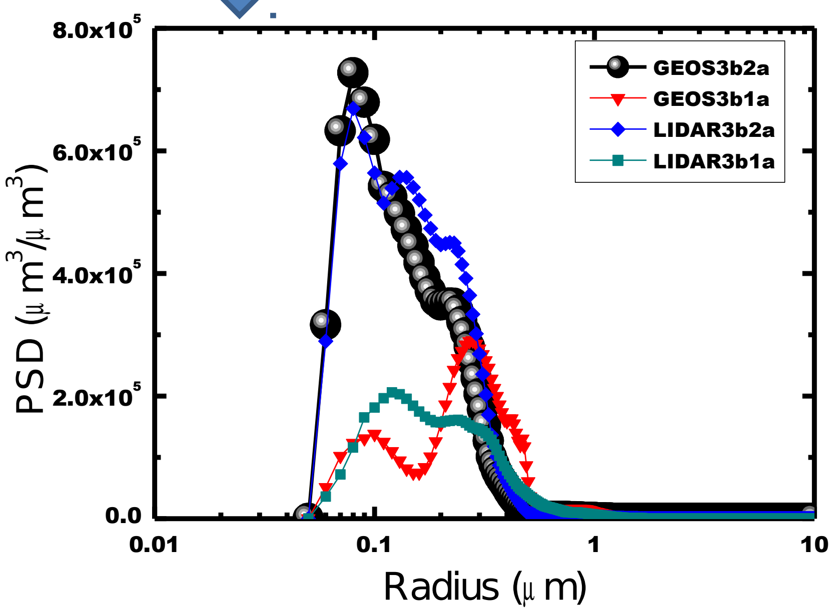
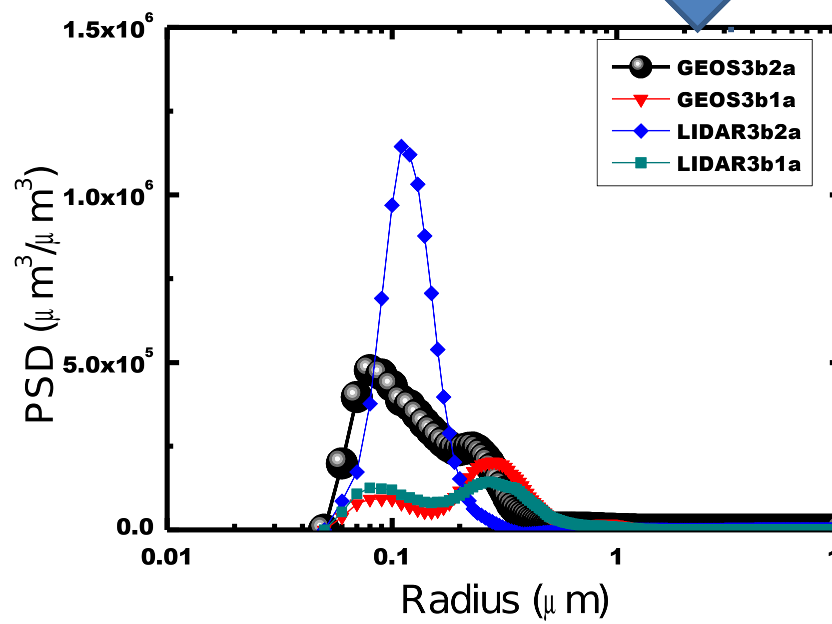
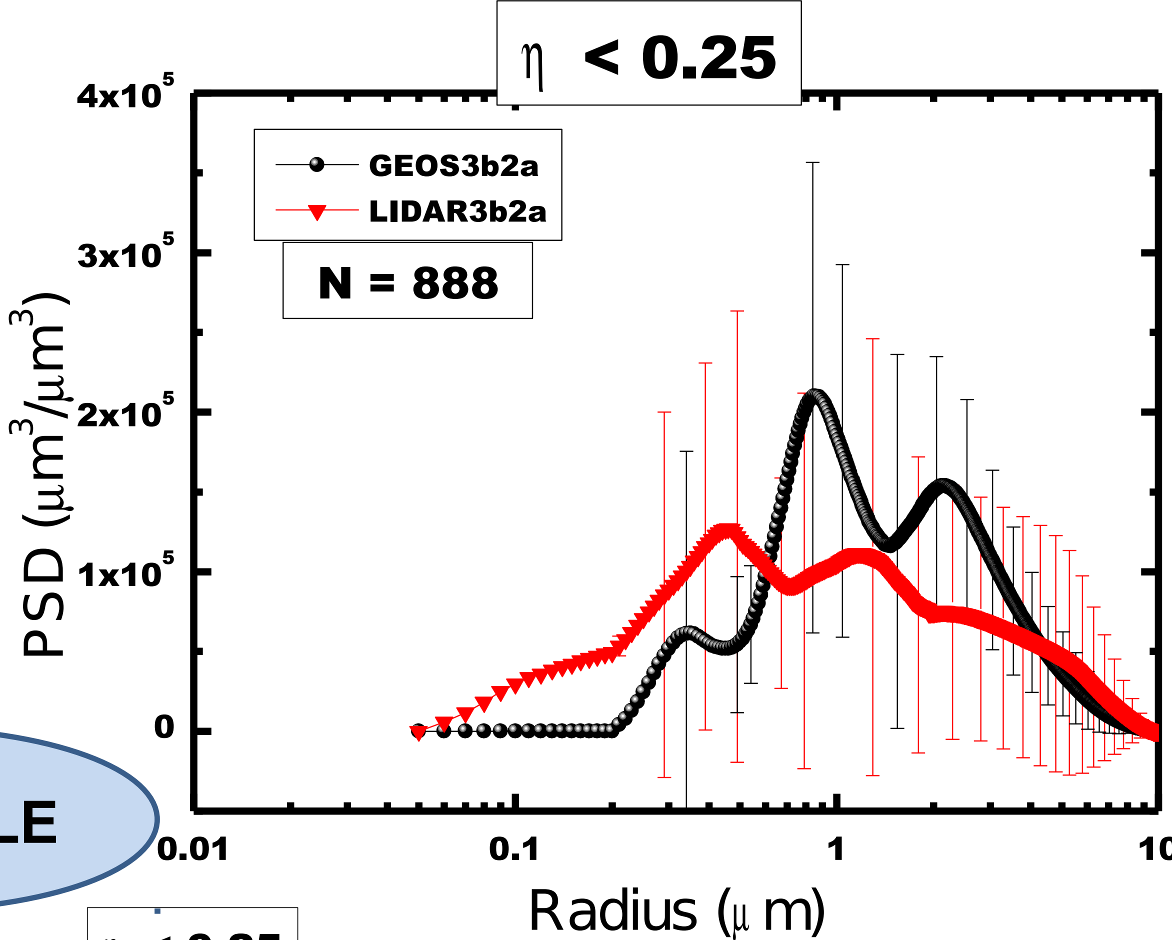
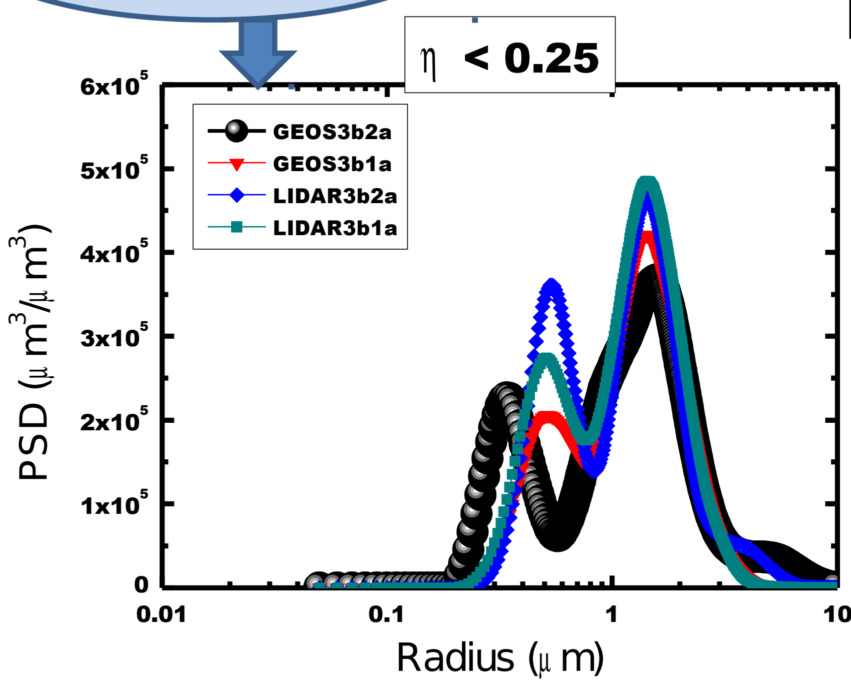




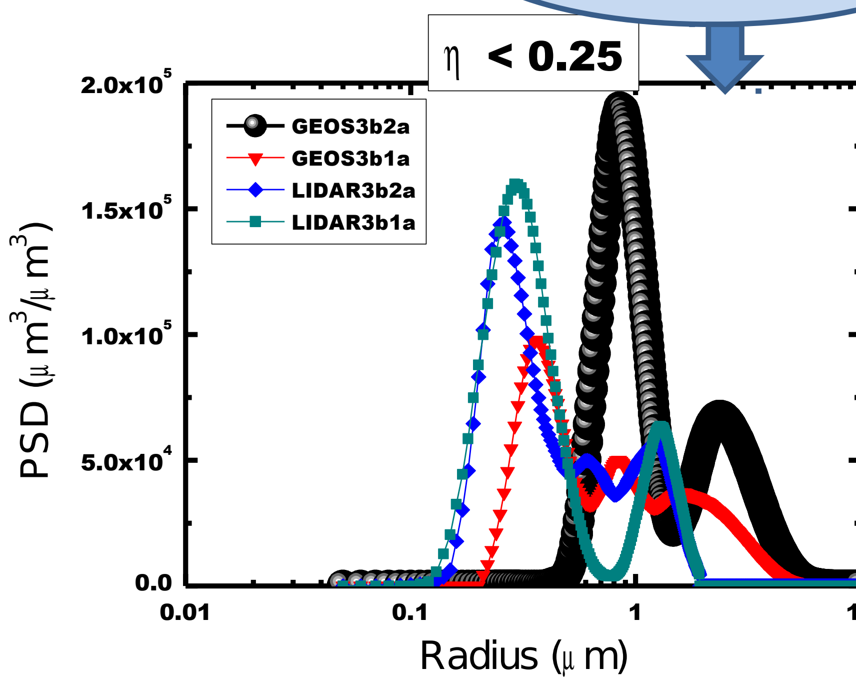


MEAN SIZE DISTRIBUTIONS: COARSE MODE PREDOMINANCE

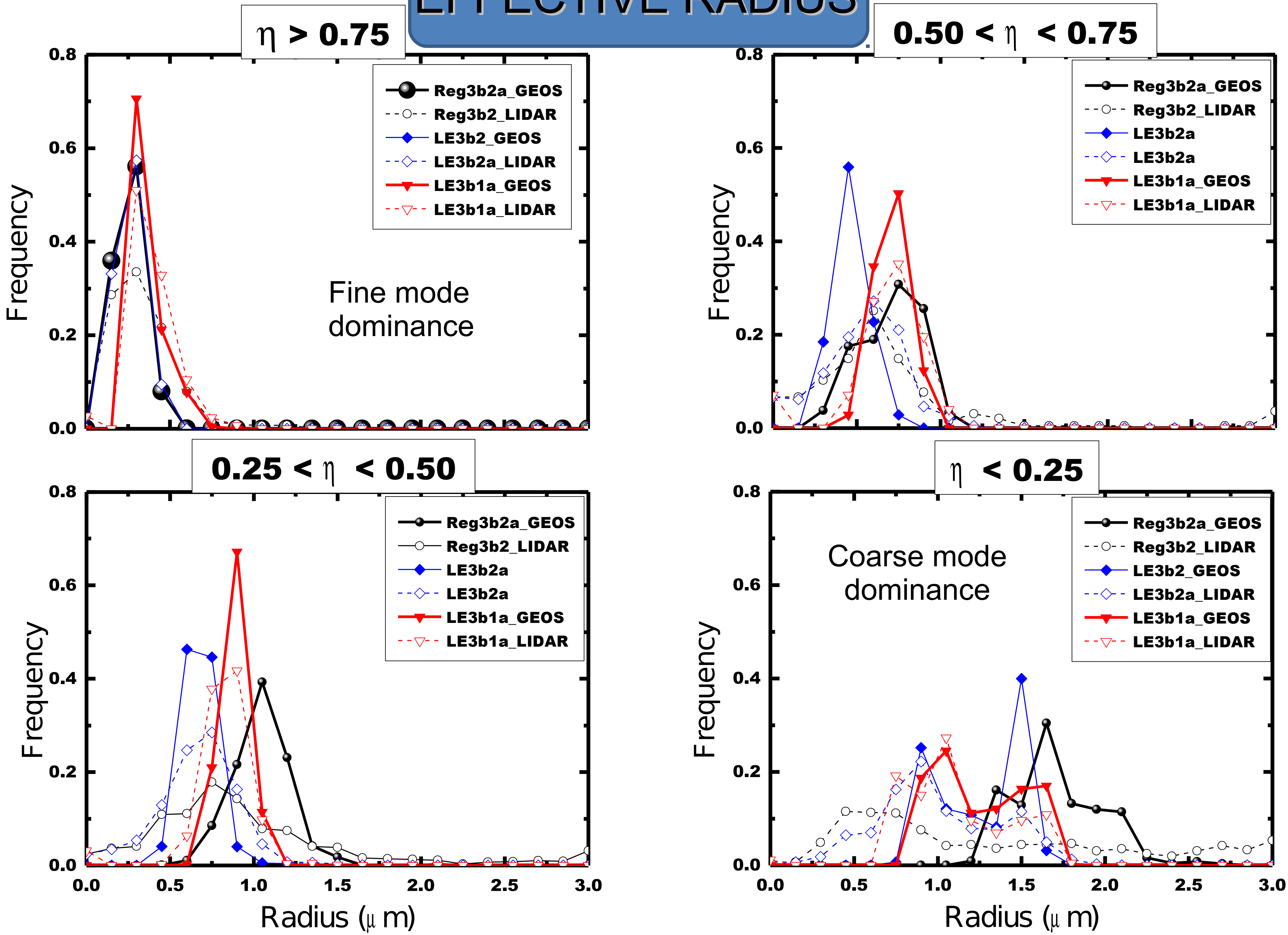
EXAMPLE



EXAMPLE



EFFECTIVE RADIUS



Next Steps

- Study simulations with 1.5 m telescope (yields will go up) and from 830 km (yields go down)
- Use PSDs in GEOS-5 simulations to generate optical data (Pete Colarco)
  - will provide “truth” for inversion constraint studies
  - include CALIPSO-derived cloud fields (yields will go down)
- Increase vertical resolution to study sensitivity to tenuous aerosols (yields will go up)
- Increase extinction uncertainty threshold to 20%, 25%, 30% and study microphysical retrievals (yields will go up, quality will likely go down)
- Look at day vs night yield (down/up)